Modern Military Clothing Systems

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Thermal comfort zone

the body needs to stay in narrow temperature limits

- comfort range: about 37°C ± 0.5°C (core temperature)
- exceeding these: discomfort starts
  - thermal discomfort is signal of thermal imbalance
  - perception of discomfort varies greatly on situation
- further imbalance: heat or cold strain
- finally: casualty due to hypothermia or hyperthermia

Balance between

- heat production of the body
  - depends on activity level
  - typically ranges from
    150 W (standing) to
    450 W (marching 5 km/h carrying 30 kg)
- heat loss to ambient
  - depends on ambient conditions
    - temperature, precipitation, wind

Temperature control

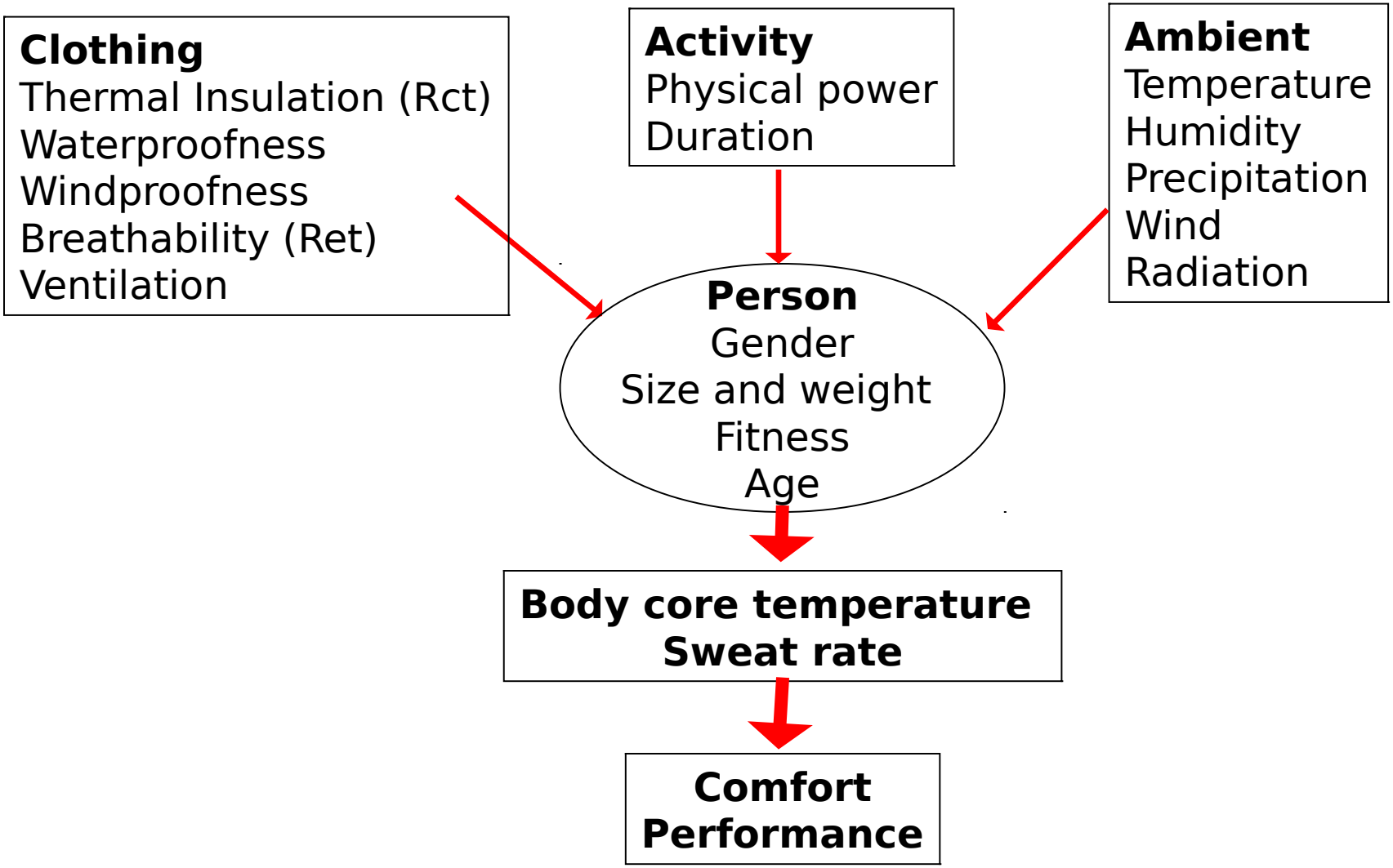
Hot side

- sweating and vasodilatation
  - evaporating 1 litre sweat per hour = 670 W heat loss
- automatic behavioural changes
  - clothing adaptation (rolling up sleeves, taking off layers)
  - reducing activity level (e.g. going slower)

Cold side

- vasoconstriction
- shivering to increase heat production
- warmer clothing

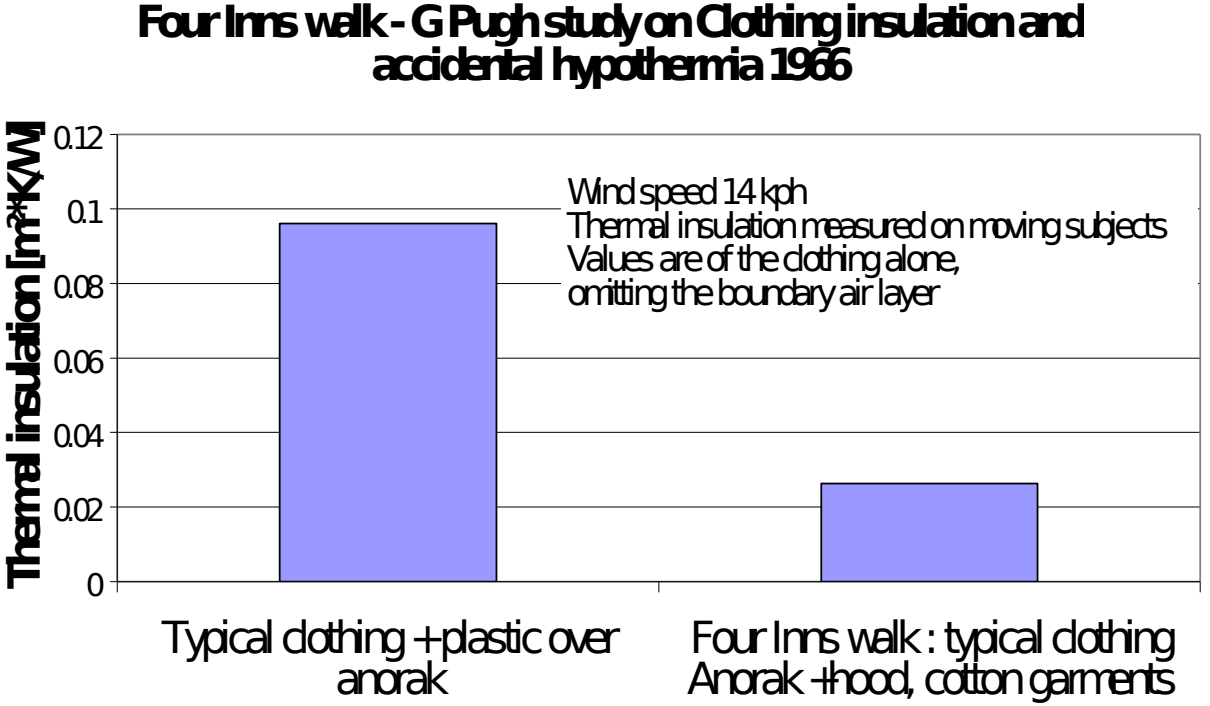
Heat balance overview



Thermal insulation and moisture

Wet insulation

- Rct reduced by about 50 to 70%
- liquid moisture is good enough for effect


Four Inns walk - G Pugh study on Clothing insulation and accidental hypothermia 1966
Thermal insulation [m²*K/W]
0.12
0.1
0.08
0.06
0.04
0.02
0
Wind speed 14 kph
Thermal insulation measured on moving subjects
Values are of the clothing alone,
omitting the boundary air layer
Typical clothing +plastic over anorak
Four Inns walk : typical clothing Anorak +hood, cotton garments

Windproofness and air permeability

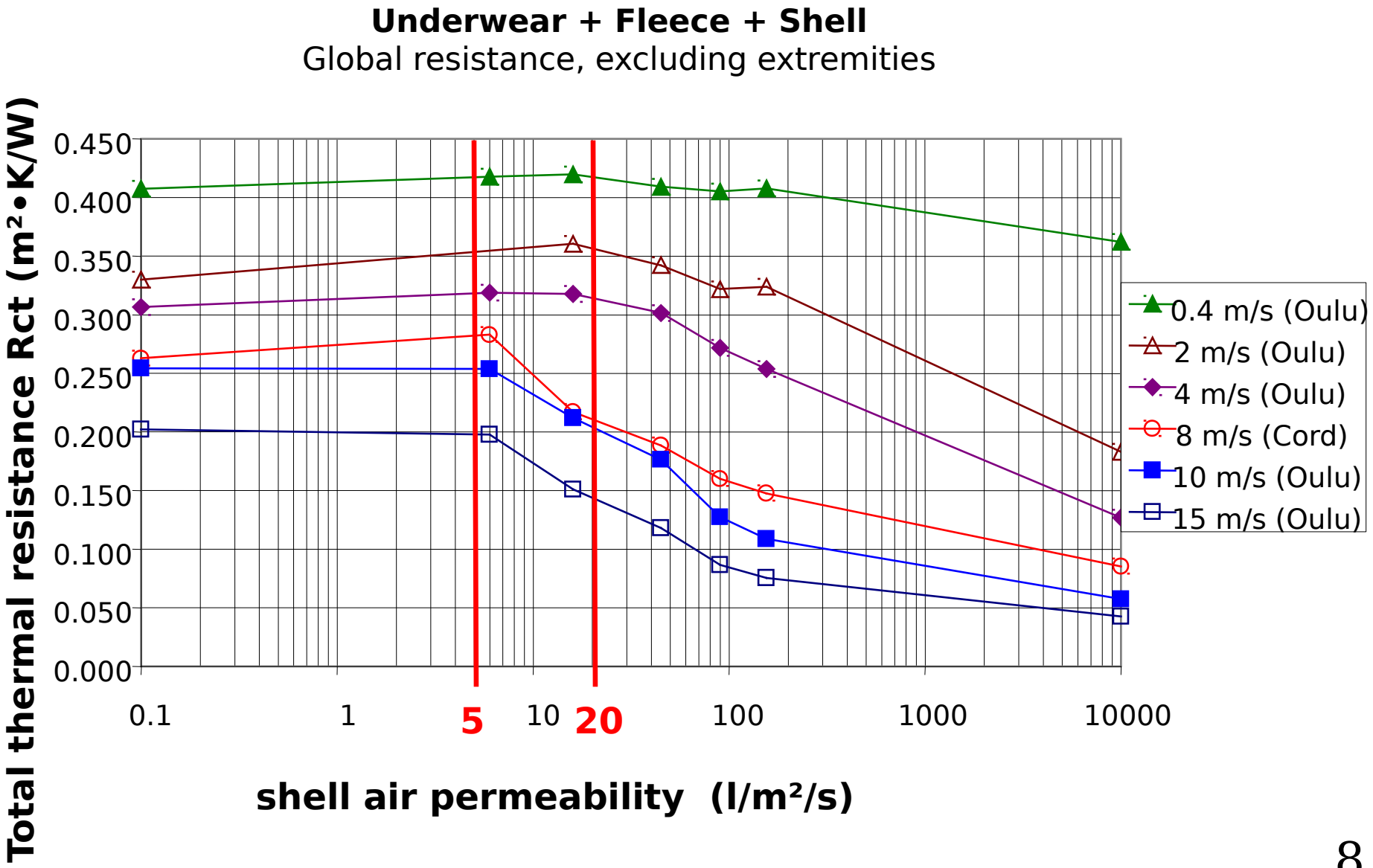
Air permeability

- measures how easy air penetrates fabrics
- expressed in l/s/m² at 100 or 200 Pa

Windproof

- air permeability according to EN342
  - class 3 current: < 20 l/s/m² at 100 Pa
  - class 3 future: < 5 l/s/m² at 100 Pa

Windproofness and wind speed



Breathability

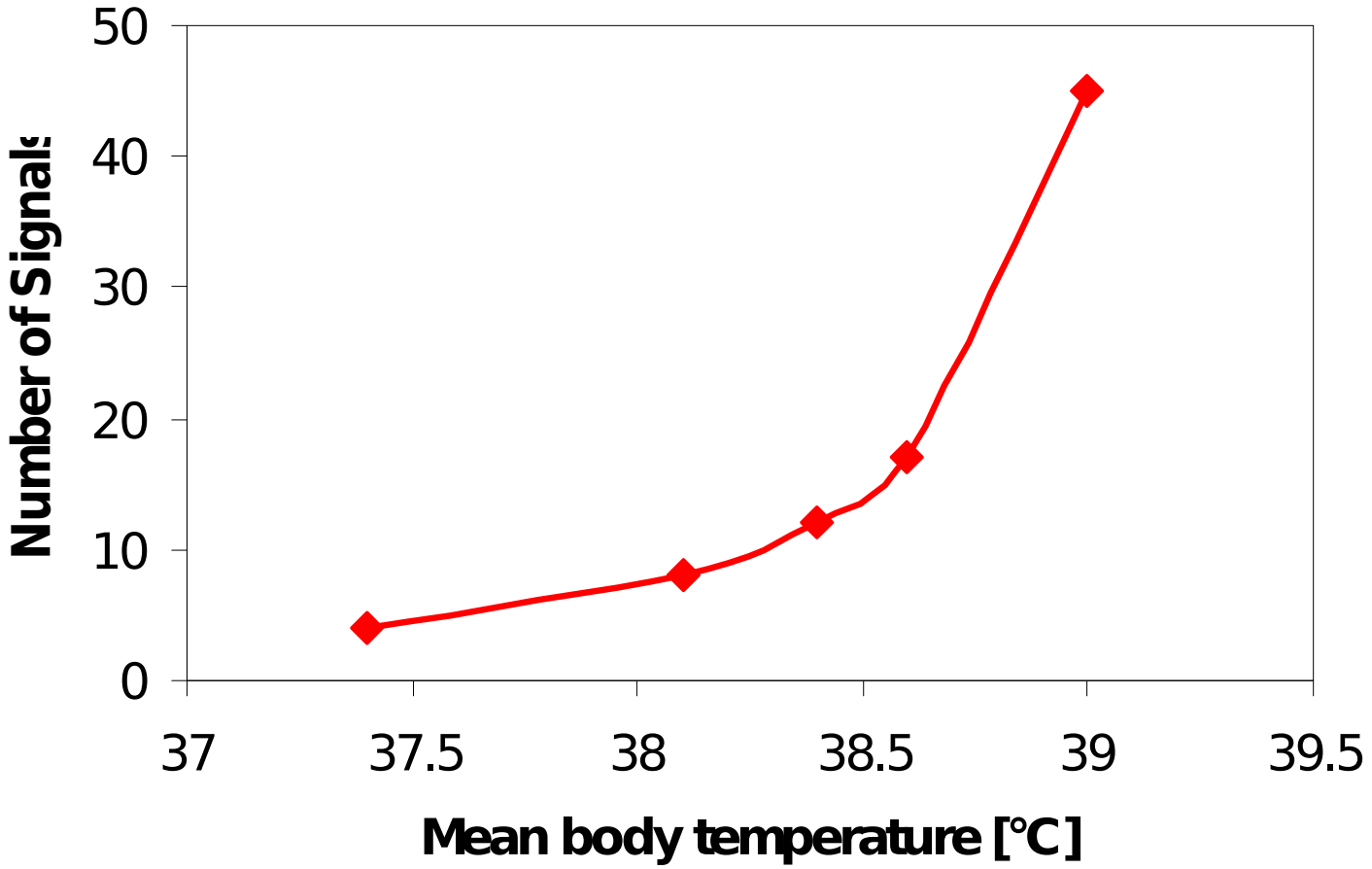
Ret - evaporative resistance of a textile

- measured on the skin model according to ISO 11092
- expressed in $m^2 \cdot Pa/W$
- thickness again is a main influence

  → high insulation always has a high Ret

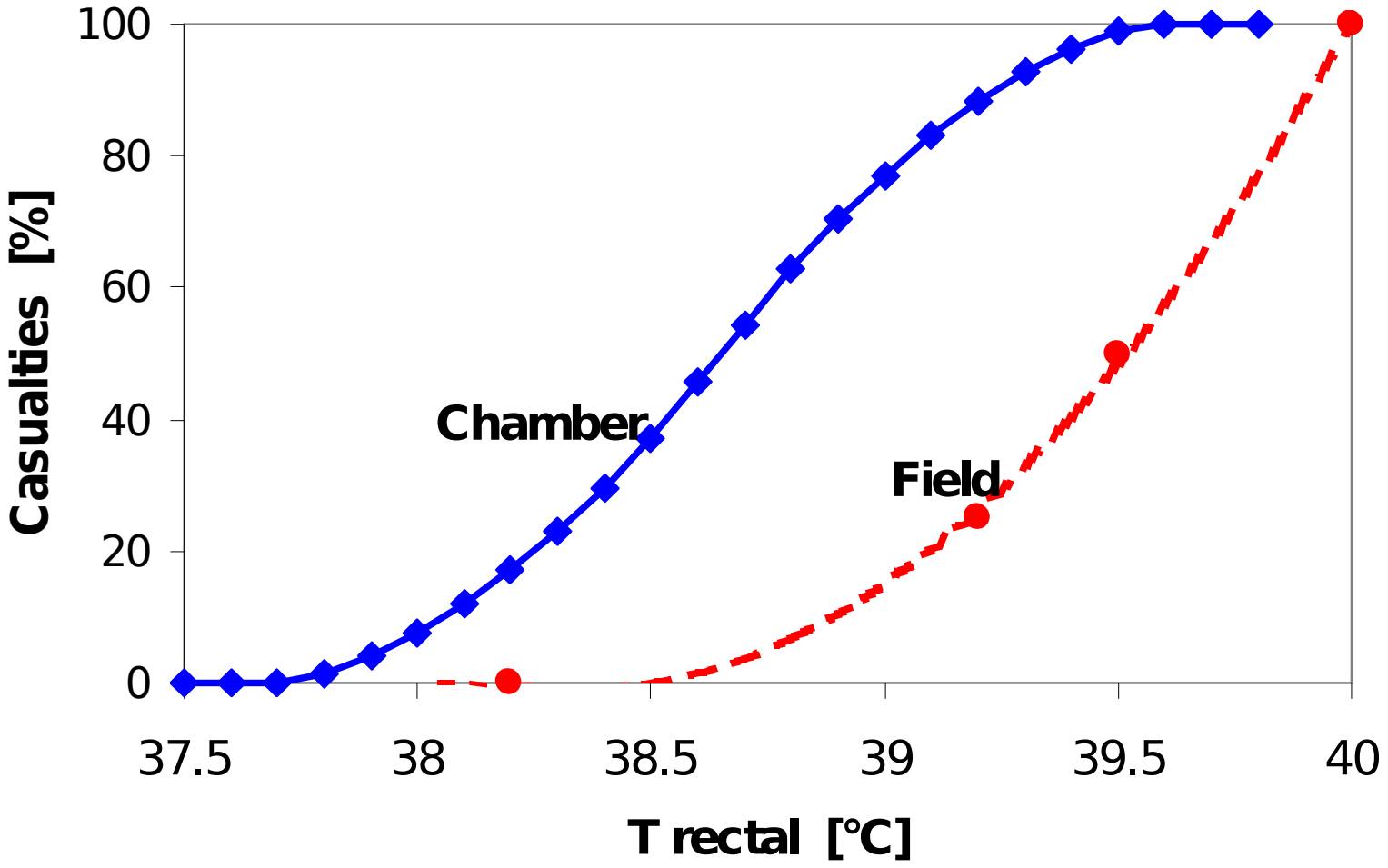
Breathability needs always to be as high as possible to keep heat strain as low as possible

Missed signals

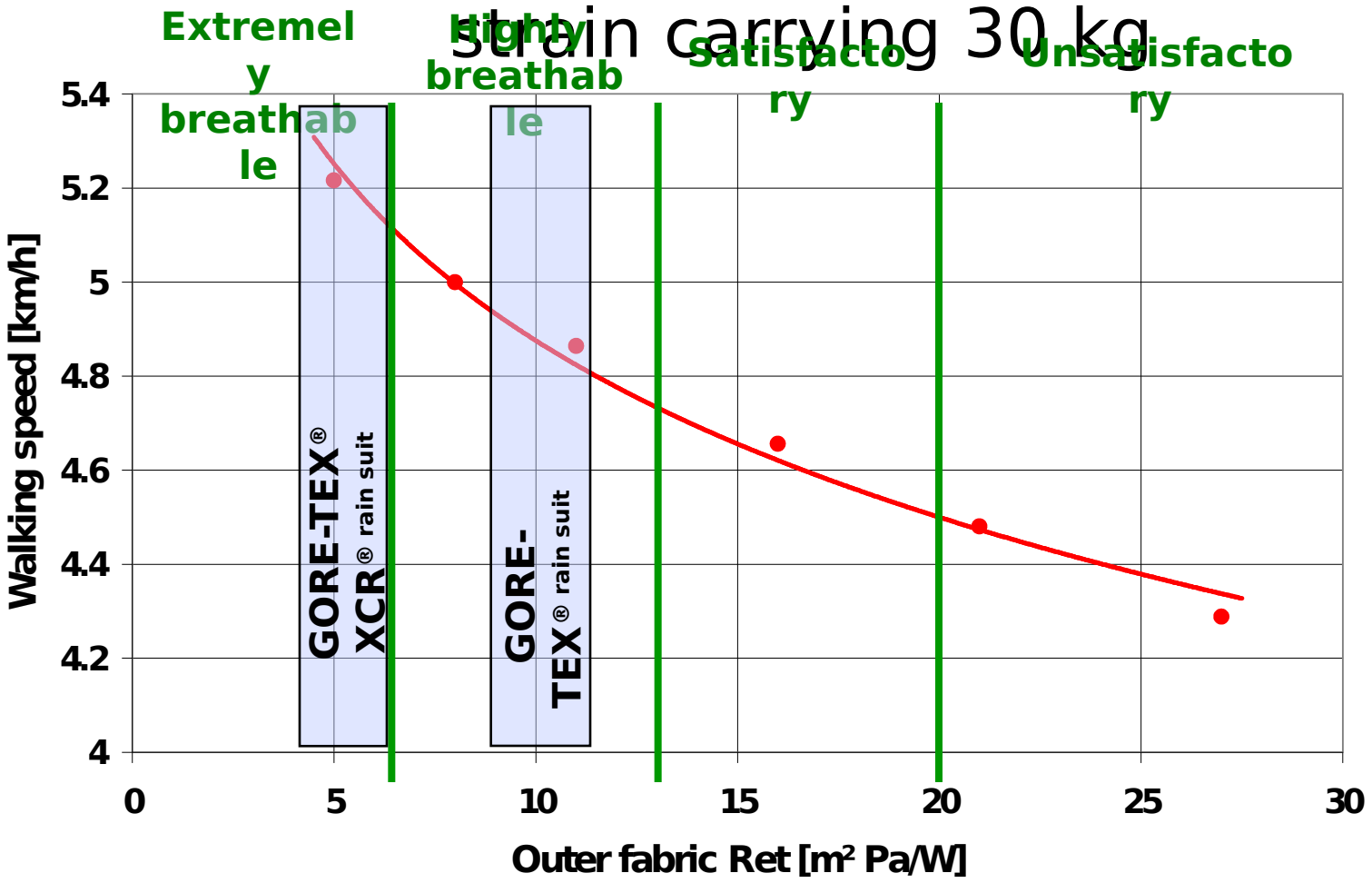


Source: P. A. Hancock, Psychological Bulletin, 1986, Vol. 99, no2 p. 263-281

Heat Casualties



Walking speed for the same heat strain carrying 30 kg



Clothing system evaluation

According to:

HOHENSTEIN INSTITUTES

Level Four: Controlled and limited Field test

Level Three: Controlled wearer tests with subjects in a Climatic Chamber

Predictive Calculations

Level Two: Biophysical analysis of clothing systems using moving thermal manikin.

Predictive Calculations

Level One: Physical analysis of fabrics using the Sweating hot plate (ISO 11092, CEN 31092) and Sensorial tests

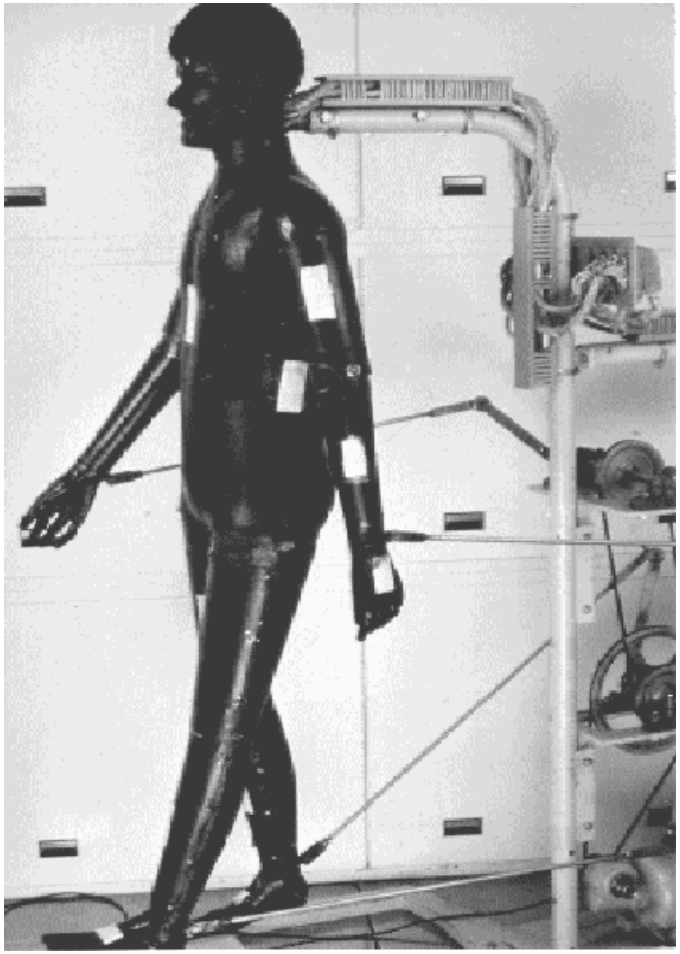
ISO 11 092 (Skin Model)
Ret and Rct measurement

Rct:
resistance to conductive heat transfer

Ret:
resistance to evaporative heat transfer

the smaller the value the more vapour permeable the fabric

Manikin testing



- **life size manikin**
- **heated**
- **articulated**
- **measurement of thermal insulation**
- **calculation of evaporative resistance**
- **few sweating manikins available**

Ventilation on humans

Ventilation rate:

- manikin don’t move natural
  → values too small

- we bought a system to measure real ventilation rates on humans carrying out realistic activities

climatic chamber trials with human subjects

Confirmation of predictions

Measurement of:

- Work rate
- body core temperature
- skin temperature
- heart rate
- subjective ratings
  - perceived exertion
  - comfort
  - etc

Controlled Field Trials

Minimum requirements according to ACCP 1:

- measurement of ambient factors
- monitor physiological factor
- standardised activities
- standardised clothing assemblies
- energy expenditure analyses

Summary

- Well designed modern clothing systems can greatly increase the performance and operational effectiveness of soldiers
- All layers and materials of a clothing ensemble have to fit and work together for optimal performance of soldier systems
- Proper design and evaluation of systems requires know how and experience